



Effects of Physical Training in Military Populations: A Meta-Analytic Summary

Ross R. Vickers, Jr.
Amanda C. Barnard

Naval Health Research Center

Report No. 11-17

The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government. Approved for public release; distribution is unlimited.

.

Naval Health Research Center
140 Sylvester Rd.
San Diego, California 92106-3521

Effects of Physical Training in Military Populations:

A Meta-Analytic Summary

Ross R. Vickers, Jr.

Amanda C. Barnard

Naval Health Research Center

140 Sylvester Road

San Diego, CA 92106-3521

e-mail: ross.vickers@med.navy.mil

This represents report 11-17 and was supported by the U.S. Department of Defense under work unit 60704. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Navy, Department of Defense, or the U.S. Government. Approved for public release; distribution is unlimited. This research has been conducted in compliance with all applicable federal regulations governing the protection of human subjects in research.

Abstract

Military physical training should increase combat readiness. Ability-performance modeling studies have shown that muscular strength and cardiovascular endurance are the keys to effective task performance, so training that improves these abilities improves readiness. This meta-analysis, which synthesized military physical training studies, showed that standard training practices produced large gains in muscular endurance and cardiovascular endurance. Standard training practices produced only minor improvements in muscular strength. Situational constraints limit the training options for military units, but some experimental programs have shown that training can be redesigned to promote muscular strength within those constraints. Modifications to training have the potential to better align training practices with readiness requirements.

Military units conduct physical training to improve combat readiness. Ability-performance modeling has shown that muscle strength and aerobic capacity are the keys to readiness (Vickers, 2009; Vickers, Hodgdon, & Beckett, 2009). Resistance training and endurance training develop these abilities (Jameson & Vickers, 2010; Vickers, Barnard, & Hervig, 2010), so appropriately designed physical training clearly could promote effective military task performance. However, military physical training is subject to time and equipment constraints. Military physical training must also promote nonphysical outcomes such as mental toughness and self-confidence. Given constraints and diffuse goals, the question arises: How much impact does traditional military physical training have on the physical abilities that are keys to readiness?

This paper reviews the research on the physical fitness outcomes from military physical training programs. The review constructs a broad training outcome profile and compares the strength and aerobic endurance outcomes with benchmarks from the physical training literature. This information provides the context for examining the alignment of military physical training with physical readiness requirements.

Methods

Literature Review

A literature search began by identifying relevant studies in the Defense Technical Information Center database and the Naval Health Research Center library. Subsequently, a PubMed search used the following keyword combinations: “physical” and “training,” “basic training” and “fitness,” and “military training” and “fitness” to identify additional articles. Article titles were reviewed as the first step in identifying relevant articles in the PubMed search.

Article abstracts were reviewed if the titles implied that the study dealt with military physical training outcomes. The full article was reviewed if the abstract indicated that the paper reported results from an experimental or quasi-experimental assessment of physical training outcomes. The article was retained for the meta-analysis if participants were drawn from a military population and the pre- and post-training means and *SD*s for one or more physical fitness outcomes were reported. The resulting set of 48 articles reported data from 96 samples (see Table 1).

Training Period

The analyses divided training effects into those produced by initial training and those produced by advanced training. Initial training studies took place during basic training, the first 8 to 12 weeks after entry into the service. Advanced training studies took the pre- and post-training measures between 12 weeks and 30 weeks after entry into the service. This temporal split reflected the fact that many recruits leave basic training and move on to some form of advanced entry-level training (e.g., Advanced Infantry Training, School of Infantry) during this time period. Too few data were available from studies conducted outside this entry-level time window to obtain reliable estimates of training effects for later phases of military service.

Training Outcomes

Training outcomes were grouped into four broad categories: muscle strength, muscle endurance, muscle power, and aerobic capacity (Hogan, 1985). Physical fitness tests were assigned to categories based on their common interpretations in the physical training literature and in work physiology research.

Any fitness test that had been investigated in only one or two samples was dropped from consideration. A single effect size (ES) might be a chance finding. Two ESs could differ widely, thereby raising questions about the representativeness of the average value. Three ESs provided a minimum basis for establishing the consistency of training effects across samples and, if necessary, to identify a given sample as an outlier relative to two other ES estimates.

Muscular strength. Strength measures included dynamic lifts, isoinertial lifts, and isometric force tests. Dynamic lift tests were multijoint lifts similar to Olympic lifts (e.g., lifting a weight from the floor to shoulder height; see Stevenson, Bryant, Greenhorn, Deakin, & Smith, 1995). Isokinetic strength was excluded because this method had been used in just one study.

Muscular endurance. Muscle endurance measures assess the ability to generate continuous or repetitive submaximal forces. Push-ups, sit-ups, and pull-ups were the only measures in this category that met the minimal data requirement for analysis.

Muscular power. Muscular power, which is sometimes known as explosive strength, is measured by tests that require short bursts of maximal muscular exertion to propel an object. Initially, this category included sprints, vertical jump, and horizontal jump. A sprint was any continuous run covering up to 400 m, including shuttle runs. However, only the vertical jump had been studied often enough to be included in the analyses.

Aerobic capacity. Aerobic capacity was measured by laboratory tests and field tests. The laboratory tests were graded exercise tests that measured maximal oxygen uptake (VO_{2max}). The field tests were distance runs covering between 1.5 and 3 miles.

Analysis Procedures

A random effects (RE) meta-analysis was performed (Borenstein, Hedges, Higgins, & Rothstein, 2009). An RE model was chosen for two reasons. First, the results could be legitimately generalized beyond the studies in the analysis. Second, it was unlikely a priori that all samples would share a common ES for any outcome, because training practices change over time and training methods and emphases differ between services.

The RE analysis proceeded as follows. The pooled *SD* for the pre and posttraining scores was computed. The difference between the posttraining average and the pretraining average was divided by the pooled *SD* to obtain Cohen's *d*. Hedge's (1981) bias correction converted *d* to *g*, the ES index used in the analyses. An initial fixed effects analysis provided an estimate of τ^2, the RE variance. The RE weight for each ES was based on its total variance, which was the sum of τ^2 and sampling variance.

The assessment of strength outcomes required preliminary work before the RE analysis could be carried out. Some studies administered multiple strength tests. Treating each strength test as an independent estimate of training effects would have given too much weight to samples that completed multiple tests. To avoid this, the strength test ESs were based on the overall average scores for the set of strength tests used in the study. The mean values for individual tests were averaged to obtain overall pre- and post-training strength test scores. The variances of the overall average scores were computed by combining the reported *SD*s for the individual tests scores with estimates of the inter-test correlations (see Nunnally & Bernstein, 1994, p. 162). As no study reported the inter-test correlations, estimates had to be derived from results reported in other studies. The inter-test correlation estimates were: dynamic strength, $r = .89$, $k = 5$, $N =$ 1,353 participants; isoinertial strength, $r = .59$, $k = 8$, $N = 1{,}204$; isometric strength, $r = .41$, $k =$ 3, $N = 301$. The pre and posttraining cumulative average scores and associated cumulative *SD*s defined the strength ES.

The general RE method was applied individually to each outcome that was represented in the data by three or more independent ES estimates. This decision balanced Borenstein et al.'s

(2009) recommendation of at least five ES estimates for RE modeling against the desire to have the broadest possible coverage of training outcomes. However, the potential inaccuracy in τ^2 estimates should be kept in mind when examining the results for infrequently studied outcomes.

Cohen's (1988) ES criteria provided the framework for interpreting the pooled ES values. Each pooled effect was classified as trivial (i.e., ES < .20), small (i.e., .20 ≤ ES < .50), medium (i.e., .50 ≤ ES < .80), or large (i.e., ES ≥ .80). These ES criteria have simple practical interpretations. A small ES meant that training shifted the score distribution enough so that 60% to 70% of program participants' posttraining scores were higher than the pretraining average. A moderate ES meant that 70% to 80% of post-training scores exceeded the pre-training average. A large ES meant that more than 80% of posttraining scores exceeded the pretraining average. The training effect was trivial if fewer than 60% of posttraining scores exceeded the pretraining average.

An SPSS syntax program was constructed to implement Borenstein et al.'s (2009) procedures. Program accuracy was verified by repeating the analysis examples in the text. All analyses were performed using SPSS-PC, version 17, computer software.

Results

Standard Training

Initial training. Nine initial training outcomes met the $k \geq 3$ criterion (Table 2). Initial training produced moderate to large effects on muscular endurance (sit-ups, push-ups, pull-ups) and cardiovascular endurance (distance runs, VO_{2max}). The initial training effects for muscular strength and power were trivial except for a small effect on isometric strength.

Advanced training. The advanced training studies reported 31 ESs for eight outcomes (Table 3). The advanced training effects were uniformly weak. The dynamic strength outcome

(ES = .374) appears to be at odds with this generalization, but this appearance should be judged in the context of the wide confidence interval for the ES estimate. The confidence interval includes ES = .00, so there is reason to downplay the apparent deviation from the general trend.

Benchmark Comparison

The benchmark comparisons focused on muscle strength and cardiovascular endurance. The benchmarks were ESs associated with typical resistance and aerobic training programs implemented with untrained participants. A typical strength program involved three training sessions per week with three sets of each exercise and 8 to 10 repetitions per set. A typical aerobic training program consisted of training 3 days per week for 31to 45 min at ~75% to 80% of VO_{2max}. The typical resistance training program produced ES = 1.045 for isoinertial strength measures ($k = 28$). The typical aerobic training program produced ES = .756 for VO_{2max} ($k = 31$).

Military training gains were significantly smaller than the benchmarks. Strength gains were 14% of the benchmark ($z = -10.09$, $p < .001$). Aerobic gains were 79% of the benchmark ($z = -4.04$, $p < .001$).

Experimental Training

Can training be more productive within military training constraints? Past experiments provide an empirical basis for answering this question. The literature describing those experiments is diffuse. Training goals have varied from study to study and the experimental programs have been matched to the goals. The program differences make it unreasonable to speak of the typical or average experimental program training effect. Therefore, experimental programs are considered here on a study-by-study basis.

The experimental training programs review focused on two basic questions. First, did the experimental program yield training outcomes that were significantly better than the standard program outcomes? If so, was the difference large enough to be practically important? The first question had to be asked to rule out the possibility that an observed difference was a chance finding (Abelson, 1997). The second question allowed for the possibility that a large sample size had inflated the apparent importance of a small difference (Rosenthal & Rosnow, 1984).

Harman, et al. (2008). This experimental program, which was conducted during the initial training period, added resistance training to the standard program. Compared with the standard program, the experimental program produced larger gains in isoinertial strength, VO_{2max}, and vertical jump. The experimental program produced smaller gains in sit-ups, push-ups, and long-distance run performance, but these gains were only small relative to the large improvement typical of standard training. The simple experimental ES was moderate to large ($.74 \leq$ ES ≤ 1.26) for each of these “impaired” outcomes.

Knapik et al. (2005). This study, which was conducted during the initial training period, introduced a complex variation on standard training. The experiment introduced ability group runs, stretching, movement drills, and calisthenics. The calisthenics included push-ups, pull-ups, and sit-ups. The experimental program produced dramatically larger gains in sit-up performance (men, ES = 1.45, $t = 14.50$, $p < .001$; women, ES = 1.95, $t = 16.25$, $p < .001$). The experimental push-up gains equaled the standard program gains (men, ES = .08, $t = 1.13$, $p = .130$; women, ES = .03, $t = .32$, $p = .374$). Overall, the program improved sit-up outcomes and maintained push-up outcomes.

Santtila, Keijo, Laura, and Heikki (2008). This study included two experimental modifications to initial training. One experimental group participated in a program that emphasized endurance training. The other experimental group participated in a program that emphasized strength training. Both modifications were superimposed on standard training. The programs produced small, statistically nonsignificant improvements in isoinertial strength and VO_{2max}. The experimental gains were not significantly different from the standard training gains.

Williams, Rayson, and Jones (2002). The experimental program in this study, which was conducted during the initial training period, included resistance training and augmented endurance training. The experimental program produced larger VO_{2max} and dynamic strength gains than seen with standard training (Table 5). The experimental program produced small, statistically nonsignificant decrements in isometric strength that contrasted with small positive effects in standard training (see Table 2). The resulting difference was statistically significant for men.

Rasch, Otott, Wilson, Brown, and Norton (1965). This study implemented two experimental programs during initial training. Each experimental program combined interval training with circuit training. One group performed the two types of training on different days, while the other group performed both each training day. Isometric strength and pull-up performance were the only measured training outcomes that met the inclusion criteria for the analysis. The experimental outcomes were no different from the standard outcomes. This negative finding may not be surprising given that the nominal experimental programs were standard training for other countries.

Knapik, Bahrke, Staab, Reynolds, and Vogel (1990). This study, which was conducted during advanced training, examined the effects of systematically training for loaded road marches. The experiment added loaded training marches to the standard training program. Three experimental programs were defined by varying the number of marches per week. A group that performed no loaded marches provided a control comparison. The training outcomes were sit-ups, push-ups, and long-distance run performance. Experimental outcomes generally approximated standard outcomes; differences were small and not statistically significant (Table 6).

Kraemer et al. (2004). This study, which was conducted during the advanced training period, examined the separate and combined effects of augmented endurance training and resistance training. One experimental program focused solely on endurance training, a second experimental program focused entirely on resistance training. The two remaining experimental programs combined resistance training and endurance training. One combined program consisted of whole-body resistance training and endurance training; the other combined program consisted of upper body resistance training and endurance training. The experimental programs produced better outcomes than standard training in 11 of 12 comparisons with sit-ups, push-ups, and long-distance run performance as outcomes (Table 7). The differences were moderate to large, and 6 of the 11 were statistically significant. The exception to the general trend was the null effect of resistance training on long-distance run performance. However, even this result did not indicate a significantly poorer outcome because long-distance run performance improves only slightly in standard advanced training.

Males, Sekulic, and Katic (2004). Males et al. studied an experimental program during advanced training. The program increased the frequency and intensity of standard training activities. Specifically, the experimental program (when compared with the control program) implemented more intense aerobic training that pushed the subjects into an anaerobic endurance zone. In addition, the experimental program included twice the amount of flexibility training as the control group. Relative to standard training, the experiment produced moderate to large, statistically significant improvements in isoinertial strength, sit-ups, push-ups, pull-ups, and long-distance runs (Table 8).

Knapik et al. (2004). This study evaluated a new Army Physical Readiness Training program implemented in advanced training. The new program combined progressive calisthenics with movement exercises, interval running, and ability-group endurance runs. The new program produced trivial improvements relative to standard training (Table 9). Those small differences were statistically significant because the sample was very large. However, this program may have two advantages over traditional training: the injury rate was lower (see Vickers, 2007, for the combined results of several studies), and the cardiovascular endurance gains were achieved with less running distance.

Summary of findings for experimental training programs. On the whole, the experimental programs produced better outcomes than standard training. When the specific effects of the various programs are considered, the programs implemented by Harman and colleagues (2008) and Williams (2005) are the most promising. Both of those programs improved strength and cardiovascular endurance, so both should better align training with performance requirements effects that should translate into improvements in task performance (Vickers, 2009; Vickers, Hodgdon, & Beckett, 2009).

Discussion

Initial training dramatically improved muscular endurance and cardiovascular endurance. Those outcomes contrasted markedly with trivial changes in muscular strength and muscular power.

Advanced training gains were much smaller than initial training gains. This result was predictable because training routinely produces smaller gains in subjects with higher levels of initial fitness than in less fit subjects (Jameson & Vickers, 2010; Vickers et al., 2010).

The alignment of training with military task demands could be improved. Performance modeling implicates muscular strength and cardiovascular endurance as the most important physical abilities for military tasks (see Vickers, 2009; Vickers et al., 2009). Standard training produces substantial cardiovascular endurance gains, but does little to develop muscular strength. Modifying programs to provide greater strength gains would better align training with performance requirements.

Program modifications are feasible. Experimental training programs have had much stronger effects on the critical abilities with little or no loss in the benefits derived from standard training. The experimental training programs that have been introduced fit the constraints found in military settings. The experimental modifications vary too widely to be encapsulated by a general summary, but there is evidence that properly designed programs can produce better muscular strength and cardiovascular endurance outcomes than current training practices (Harman et al., 2008; Williams et al., 2002). Other programs have shown that current training outcomes can be maintained while reducing the injury rate (see Vickers, 2007, summary of work by Knapik and colleagues). Greater use of either type of program will produce a higher net readiness level for military units.

The fitness elements that are most affected by standard training suggest a mechanism for aligning training with readiness requirements. Standard training has produced major gains in sit-up, push-up, pull-up, and long-distance run performances. Each of these outcomes is a common element of military physical fitness tests. The substantial improvements in these measures suggest that training programs “train to the test.” Introducing suitable physical readiness tests could bring this same tendency to bear on muscular strength and muscular power. For example, the Combat Fitness Test (CFT) recently implemented by the U.S. Marine Corps includes elements that appear to depend on muscular power. CFT implementation can be expected to increase the emphasis on developing muscular power.

One major gap in the evidence could be critical for combat readiness. Studies of military physical training have been limited almost entirely to the first 6 months of service. The paucity of data on the effects of later training means that little or nothing is known about the effectiveness of training that takes place in the crucial period(s) leading up to combat deployment. Extrapolating from the modest gains seen in advanced training, subsequent training may do little more than maintain the fitness achieved during entry-level training. Simple maintenance is acceptable if earlier training has produced the physical capabilities needed to meet operational demands. In fact, the opportunity cost of investing time and other resources in physical training might not justify increased physical training. The time and other resources might be better spent on other performance improvement methods (e.g., small-unit tactical training).

The available evidence limits the precision and scope of the inferences that can be drawn from this review. Few outcomes have been studied enough to develop precise training effect estimates. The emphasis on recruit training, while admittedly focused on a critical period of each recruit's service, makes it impossible to determine the effects of training later in the individual's military service. Experimental programs have shown promise, but only a few possibilities have been investigated. The experiments that have been tried have not been replicated, so caution is appropriate when making assertions about their effects. Finally, the distinction between standard training and experiments may be inconsistent in a review that draws on data from a time span of nearly 50 years. Today's experiment, if successful, can become tomorrow's standard method.

Each of these limitations represents an opportunity for additional constructive research to align physical training with readiness.

In conclusion, initial military physical training develops muscular endurance and cardiovascular endurance. Advanced physical training adds little to the initial gains. Consideration should be given to modifying traditional training practices to improve muscular strength and muscular power outcomes. Recent U.S. Marine Corps instructions provide the policy context for novel program designs (Commandant of the Marine Corps, 2002, 2008). The road ahead should include systematic evaluation of training options designed to align physical training practices with anticipated combat requirements. The recent implementation of the CFT provides organizational incentive for changing training practices within the U.S. Marine Corps. Steps could be taken to capitalize on the resulting opportunity to implement and formally evaluate alternative training regimens.

References

*References marked with an asterisk indicates studies that provided data for the analyses.

Abelson, R. P. (1997). A retrospective on the significance test ban of 1999 (If there were no significance tests, they would be invented). In L. L. Harlow, S. A. Mulaik & J. H. Steiger (Eds.), *What if there were no significance tests?* (pp. 117–141). Mahwah, NJ: Lawrence Erlbaum.

*Bell, N. S., Mangione, T. W., Hemenway, D., Amoroso, P. J., & Jones, B. H. (2000). High injury rates among female Army trainees: A function of gender? *American Journal of Preventive Medicine, 18*(Suppl. 3), 141–146.

*Blacker, S. D., Wilkinson, D. M., & Rayson, M. P. (2009). Gender differences in the physical demands of British Army recruit training. *Military Medicine, 174*(8), 811–816.

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). *Introduction to meta-analysis*. Chichester, West Sussex, UK: John Wiley and Sons.

*Brock, J. R., & Legg, S. J. (1997). The effects of 6 weeks training on the physical fitness of female recruits to the British Army. *Ergonomics, 40*(3), 400–411.

*Chai, L. Y., Ong, K. C., Kee, A., Earnest, A., Lim, F. C., & Wong, J. C. (2009). A prospective cohort study on the impact of a modified Basic Military Training (mBMT) programme based on pre-enlistment fitness stratification amongst Asian military enlistees. *Annals of the Academy of Medicine Singapore, 38*(10), 862–868.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Commandant of the Marine Corps. (May 2002). *Marine Corps Physical Fitness Test and Body Composition Program (Short title: MCPFTBCP)* (Marine Corps Order P6100.12 W/CH 1). Washington, DC: Headquarters, United States Marine Corps.

Commandant of the Marine Corps. (August 2008). *Marine Corps physical fitness instruction* (Marine Corps Order 6100.13). Washington, DC: Headquarters, United States Marine Corps.

*Daniels, W. L., Kowal, D. M., Vogel, J. A., & Stauffer, R. M. (1979). Physiological effects of a military training program on male and female cadets. *Aviation, Space, and Environmental Medicine, 50*(6), 562–566.

*Dyrstad, S. M., Soltvedt, R., & Hallen, J. (2006). Physical fitness and physical training during Norwegian military service. *Military Medicine, 171*(8), 736–741.

*Etzweiler, S. W., Kraemer, W. J., Nindl, B. C., Gotshalk, L. A., Dohi, K., Fredman, B. S.,…Häkkinen, K. (1998). The effects of resistance training on a high intensity manual materials handling task in women. *Medicine and Science in Sports and Exercise, 30*(5), 318.

*Evans, R. K., Antczak, A. J., Lester, M., Yanovich, R., Israeli, E., & Moran, D. S. (2008). Effects of a 4-month recruit training program on markers of bone metabolism. *Medicine and Science in Sports and Exercise, 40*(Suppl. 11), S660–670.

*Faff, J., & Korneta, K. (2000). Changes in aerobic and anaerobic fitness in the Polish Army paratroopers during their military service. *Aviation, Space, and Environmental Medicine, 71*(9), 920–924.

*Faff, J., Satora, P., & Stasiak, K. (2002). Changes in the aerobic and anaerobic capacities of Army recruits during their military training are related to the initial level of physical fitness of the subjects. *Biology of Sport, 19*, 251–265.

*Finestone, A., Milgrom, C., Evans, R., Yanovich, R., Constantini, N., & Moran, D. S. (2008). Overuse injuries in female infantry recruits during low-intensity basic training. *Medicine and Science in Sports and Exercise, 40*(Suppl. 11), S630–635.

*Harman, E. A., Frykman, P. N., Lammi, E., & Palmer, C. (2008). Effects of physically demanding training program on women's heavy task work performance. *Medicine and Science in Sports and Exercise, 28*(5), 128.

*Harman, E. A., Gutekunst, D. J., Frykman, P. N., Nindl, B. C., Alemany, J. A., Mello, R. P., & Sharp, M. A. (2008). Effects of two different eight-week training programs on military physical performance. *Journal of Strength and Conditioning Research, 22*(2), 524–534.

*Harwood, G. E., Rayson, M. P., & Nevill, A. M. (1999). Fitness, performance, and risk of injury in British Army officer cadets. *Military Medicine, 164*(6), 428–434.

Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational Statistics, 6*, 107–128.

Hogan, J. (1985). Tests for success in diver training. *Journal of Applied Psychology, 70*(1), 219–224.

Jameson, J., & Vickers, R. R., Jr. (2010). *Best practices in the design of aerobic training programs* (Report No. 10-12). San Diego, CA: Naval Health Research Center.

*Knapik, J., Bahrke, M. S., Staab, J. S., Reynolds, K., & Vogel, J. A. (1990). *Frequency of loaded road march training and performance on a loaded march* (USARIEM Report No. T13-90). Natick, MA: U.S. Army Research Institute for Environmental Medicine.

*Knapik, J., Darakjy, S., Scott, S. J., Hauret, K. G., Canada, S., Marin, R.,…Jones, B. H. (2005). Evaluation of a standardized physical training program for basic combat training. *Journal of Strength and Conditioning Research, 19*(2), 246–253.

*Knapik, J., & Gerber, J. (1996). *The influence of physical fitness training on the manual material-handling capability and road-marching performance of female soldiers* (ARL Report No. 1L162716AH70). Aberdeen Proving Ground, MD: Army Research Lab.

*Knapik, J. J. (1997). The influence of physical fitness training on the manual material handling capability of women. *Applied Ergonomics, 28*(5-6), 339–345.

*Knapik, J. J., Bullock, S. H., Canada, S., Toney, E., Wells, J. D., Hoedebecke, E., & Jones, B. (2004). Influence of an injury reduction program on injury and fitness outcomes among soldiers. *Injury Prevention, 10*(1), 37–42.

*Knapik, J. J., Canham-Chervak, M., Hoedebecke, E., Hewitson, W. C., Hauret, K., Held, C., &Sharp, M. A. (2001). The Fitness Training Unit in U.S. Army basic combat training: Physical fitness, training outcomes, and injuries. *Military Medicine, 166*(4), 356–361.

*Knapik, J. J., Hauret, K. G., Arnold, S., Canham-Chervak, M., Mansfield, A. J., Hoedebecke, E. L.,…McMillian, D. (2003). Injury and fitness outcomes during implementation of physical readiness training. *International Journal of Sports Medicine, 24*(5), 372–381.

*Knapik, J. J., Scott, S. J., Sharp, M. A., Hauret, K. G., Darakjy, S., Rieger, W. R.,…Jones, B. H. (2006). The basis for prescribed ability group run speeds and distances in U.S. Army basic combat training. *Military Medicine, 171*(7), 669–677.

*Knapik, J. J., Wright, J. E., Kowal, D. M., & Vogel, J. A. (1980). The influence of U.S. Army Basic Initial Entry Training on the muscular strength of men and women. *Aviation, Space, and Environmental Medicine, 51*(10), 1086–1090.

*Kowal, D. M., Patton, J. F., & Vogel, J. A. (1978). Psychological states and aerobic fitness of male and female recruits before and after basic training. *Aviation, Space, and Environmental Medicine, 49*(4), 603–606.

*Kraemer, W. J., Vescovi, J. D., Volek, J. S., Nindl, B. C., Newton, R. U., Patton, J. F.,…Häkkinen, K. (2004). Effects of concurrent resistance and aerobic training on load-bearing performance and the Army Physical Fitness Test. *Military Medicine, 169*(12), 994–999.

*Legg, S. J., & Duggan, A. (1996). The effects of basic training on aerobic fitness and muscular strength and endurance of British Army recruits. *Ergonomics, 39*(12), 1403–1418.

*Lieberman, H. R., Kellogg, M. D., & Bathalon, G. P. (2008). Female Marine recruit training: mood, body composition, and biochemical changes. *Medicine and Science in Sports and Exercise, 40*(Suppl. 11), S671–676.

*Lim, C. L., & Lee, L. K. (1994). The effects of 20 weeks basic military training program on body composition, VO2max and aerobic fitness of obese recruits. *Journal of Sports Medicine and Physical Fitness, 34*(3), 271–278.

*Males, B., Sekulic, D., & Katic, R. (2004). Morphological and motor-endurance changes are highly related in Croatian Navy male recruits. *Military Medicine, 169*(1), 65–70.

*Maloney, J. P., Cheney, R., Spring, W., & Kanusky, J. (1986). The physiologic and psychological effects of a 5-week and a 16-week physical fitness program. *Military Medicine, 151*(8), 426–433.

*Myers, D. C., Gebhardt, D. L., Crump, C. E., & Fleishman, E. A. (1984). *Validation of the Military Entrance Physical Strength Capacity Test* (USARIEM Report No. 610). Natick, MA: U.S. Army Research Institute for Environmental Medicine.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). New York: McGraw-Hill.

*Patton, J. F., Daniels, W. L., & Vogel, J. A. (1980). Aerobic power and body fat of men and women during Army basic training. *Aviation, Space, and Environmental Medicine, 51*(5), 492–496.

*Rasch, P. J., Otott, G. E., Wilson, I. D., Brown, M. T., & Norton, R. J. (1965). Evaluation of an experimental combat conditioning course and of physical fitness tests (Task MR005.01-0030.6.1). *Research Report U.S. Naval Medical Field Research Laboratory, 15*, 1–35.

*Rosendal, L., Langberg, H., Skov-Jensen, A., & Kjaer, M. (2003). Incidence of injury and physical performance adaptations during military training. *Clinical Journal of Sports Medicine, 13*(3), 157–163.

Rosenthal, R., & Rosnow, R. L. (1984). *Essentials of behavioral research*. New York: McGraw-Hill.

*Santtila, M., Keijo, H., Laura, K., & Heikki, K. (2008). Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. *Military Medicine, 173*(12), 1173–1179.

*Sharp, M. A., Knapik, J., Patton, J. F., Smutok, M. A., & Hauret, K. (2000). *Physical fitness of soldiers entering and leaving Basic Combat Training* (USARIEM Report No. T00-13). Natick, MA: U.S. Army Research Institute for Environmental Medicine.

*Stacy, R. J., Hungerford, R. L., & McMahon, B. B. (1982). The effect of basic training on aerobic capacity and body fat in New Zealand army recruits. *New Zealand Medical Journal, 95*(722), 876–878.

Stevenson, J., Bryant, T., Greenhorn, D., Deakin, J., & Smith, T. (1995). Development of factor-score-based models to explain and predict maximal box-lifting performance. *Ergonomics, 38*(2), 292–302.

*Teves, M. A., Wright, J. E., & Vogel, J. A. (1985). *Performance on selected candidate screening test procedures before and after Army Basic and Advanced Individual Training* (USARIEM Report No T13/85). Natick, MA: U.S. Army Research Institute for Environmental Medicine.

*Trank, T. V., Ryman, D. H., Minagawa, R. Y., Trone, D. W., & Shaffer, R. A. (2001). Running mileage, movement mileage, and fitness in male U.S. Navy recruits. *Medicine and Science in Sports and Exercise, 33*(6), 1033–1038.

Vickers, R. R., Jr. (2007). *Physical Readiness Training: A meta-analysis* (Report No. 07-20). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr. (2009). *Physical abilities and military task performance: A replication and extension* (Report No. 09-30). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Barnard, A. C., & Hervig, L. K. (2010). *Resistance training: Identifying best practices?* (Report No. 10-21). San Diego, CA: Naval Health Research Center.

Vickers, R. R., Jr., Hodgdon, J. A., & Beckett, M. B. (2009). *Physical ability-task performance models: Assessing the risk of omitted variable bias* (Report No. 09-04). San Diego, CA: Naval Health Research Center.

*Vogel, J. A., Ramos, M. U., & Patton, J. F. (1977). Comparison of aerobic power and muscle strength between men and women entering the U.S. Army. *Medicine and Science in Sports and Exercise, 9*(1), 58.

*Westphal, K. A., Friedl, K. E., Sharp, M. A., King, M., Kramer, T. R., Reynolds, K. L., & Marchitelli, L. J. (1995). *Health, performance, and nutritional status of U.S. Army women during Basic Combat Training* (USARIEM Report No. 2(96)). Natick, MA: U.S. Army Research Institute for Environmental Medicine.

*Williams, A. G. (2005). Effects of basic training in the British Army on regular and reserve army personnel. *Journal of Strength and Conditioning Research, 19*(2), 254–259.

*Williams, A. G., & Rayson, M. P. (2006). Can simple anthropometric and physical performance tests track training-induced changes in load-carriage ability? *Military Medicine, 171*(8), 742–748.

*Williams, A. G., Rayson, M. P., & Jones, D. A. (1999). Effects of basic training on material handling ability and physical fitness of British Army recruits. *Ergonomics, 42*(8), 1114–1124.

*Williams, A. G., Rayson, M. P., & Jones, D. A. (2002). Resistance training and the enhancement of the gains in material-handling ability and physical fitness of British Army recruits during basic training. *Ergonomics, 45*(4), 267–279.

*Yanovich, R., Evans, R., Israeli, E., Constantini, N., Sharvit, N., Merkel, D.,…Moran, D. (2008). Differences in physical fitness of male and female recruits in gender-integrated Army basic training. *Medicine and Science in Sports and Exercise, 40*(Suppl. 11), S654–659.

Table 1

Demographic Characteristics

	k	ΣN	Mean	*SD*	Minimum	Maximum
Age, yr	68	304	21.23	2.76	18.0	29.0
Height	67	325	172.98	6.38	159.9	184.07
Weight	75	362	70.57	7.99	56.1	108.30
Body fat (%)	44	227	19.58	6.53	8.1	34.3

Table 2

Initial Training Effects

Outcome	*k*	Avg	*SE*	Lower	Upper	*Q*	Sig	*z*	Sig
Large effects									
Sit-ups	17	1.690	.195	1.351	2.030	13.10	.666	8.69	.000
Push-ups	15	1.561	.073	1.433	1.689	21.04	.101	21.50	.000
Long-distance run	25	1.094	.055	1.000	1.188	75.62	.000	19.89	.000
Moderate effects									
Pull-ups	4	.631	.111	.370	.893	3.02	.389	5.68	.000
Laboratory VO_{2max}	26	.441	.078	.307	.574	28.29	.295	5.64	.000
Small effects									
Isometric strength	20	.234	.076	.104	.365	23.55	.214	3.10	.001
Unimportant effects									
Dynamic strength	12	.147	.089	-.014	.307	10.23	.510	1.64	0.050
Isoinertial strength	3	-.004	.280	-.822	.814	2.64	.267	-.01	.506
Isokinetic strength	4	-.063	.110	-.323	.196	2.17	.538	-.58	.718
Vertical jump	4	-.210	.117	-.485	.065	3.07	.380	-1.80	.964

Note. Table gives random-effects analysis results for all training outcomes with ES estimates based on three or more samples. Outcomes listed from largest ES to smallest ES. ES classification based on Cohen (1988).

Table 3

Advanced Training Effects

Outcome	*k*	Avg	*SE*	Lower	Upper	*Q*	Sig	*z*	Sig
Small effects									
Dynamic strength	4	.374	.335	-.414	1.162	4.00	.262	1.12	.132
Isometric strength	5	.264	.144	-.042	.571	4.88	.300	1.84	.033
Sit-ups	5	.242	.068	.097	.387	4.72	.317	.355	.000
Long-distance run	6	.218	.128	-.039	.475	12.49	.019	1.71	.044
Push-ups	3	.204	.039	.091	.318	2.15	.342	5.25	.000
Unimportant effects									
Pull-ups	4	-.057	.104	-.302	.187	3.00	.392	-.55	.710
Isoinertial strength	3	-.144	.096	-.425	.138	1.41	.495	-.149	.932

Note. Table gives random-effects analysis results for all training outcomes with ES estimates based on three or more samples. Outcomes listed from largest ES to smallest ES. ES classification based on Cohen (1988).

Table 4

Results of Harman et al. (2008) Resistance Training Program in Initial Training

Outcome	g	SE_g	ES[a]	z[b]	Sig
Isoinertial strength	1.26	.39	1.26	3.24	.001
Sit-ups	.77	.37	-.92	-2.49	.006
Push-ups	1.14	.38	-.42	-1.11	.134
Vertical jump	.34	.36	.55	1.53	.063
VO_{2max}	1.10	.38	.66	1.73	.041
Long-distance run	.74	.37	-.35	-.96	.169

[a]ES = (Program g – Standard Training g) where the standard training g is the appropriate value from Table 3.

[b]z = ES/SE_g.

Table 5

Results of Williams et al. (2002) Resistance Training Experiment in Initial Training

Outcome	Gender	*g*	*SE*	ES[a]	*z*[b]	Sig
Dynamic strength	Men	.71	.23	.56	2.45	.007
	Women	.99	.50	.84	1.69	.046
Isometric strength	Men	-.32	.23	-.55	-2.41	.008
	Women	-.05	.47	-.28	-.60	.273
VO_{2max}	Men	.99	.26	.55	2.11	.017
	Women	3.27	.80	2.83	3.54	.000

[a]ES = (Program g – Standard Training g) where the standard training g is the appropriate value from Table 3.

[b]z = ES/SE_g.

Table 6

Results of Knapik et al. (1990) Load Carriage Experiment in Advanced Training

Outcome	Condition	*g*	*SE*	ES	*z*	Sig
Sit-ups	0 marches/week	.61	.31	.37	1.19	.118
	1 march/week	.00	.38	-.24	-.64	.262
	2 marches/week	.22	.25	-.02	-.09	.465
	4 marches/week	.12	.30	-.12	-.41	.342
Push-ups	0 marches/week	.81	.32	.61	1.89	.029
	1 march/week	.48	.39	.28	.71	.240
	2 marches/week	.53	.26	.33	1.25	.105
	4 marches/week	.53	.31	.33	1.05	.146
Long-distance run	0 marches/week	-.16	.30	-.38	-1.26	.104
	1 march/week	-.32	.38	-.54	-1.42	.078
	2 marches/week	.00	.25	-.22	-.87	.192
	4 marches/week	-.23	.30	-.45	-1.49	.068

[a]ES = (Program *g* – Standard Training *g*) where the standard training *g* is the appropriate value from Table 4.

[b]z = ES/SE_g.

Table 7

Results of Kraemer et al. (2004) Experiment in Advanced Training

Outcome	Treatment	*g*	*SE*	ES[a]	*Z*[b]	Sig
Sit-ups	Resistance	3.03	.68	2.79	4.10	.000
	Endurance	.90	.50	.66	1.32	.094
	Whole body + endurance	1.51	.51	1.27	2.49	.006
	Upper body + endurance	.91	.47	.67	1.42	.078
Push-ups	Resistance	1.96	.56	1.76	3.14	.001
	Endurance	.77	.49	.57	1.16	.124
	Whole body + endurance	1.87	.55	1.67	3.03	.0001
	Upper body + endurance	1.08	.48	.88	1.83	.034
Long-distance run	Resistance	.00	.45	-.22	-.48	.314
	Endurance	.79	.49	.57	1.14	.122
	Whole body + endurance	.83	.47	.61	1.30	.096
	Upper body + endurance	1.99	.56	1.77	3.16	.001

[a]ES = (Program g – Standard Training g) where the standard training g is the appropriate value from Table 4.

[b]z = ES/SE_g.

Table 8

Results of Males et al. (2004) Frequency and Intensity Experiment During Advanced Training

Outcome	*g*	*SE*	ES[a]	*Z*[b]	Sig
Isoinertial	.60	.10	.74	7.44	.000
Sit-ups	1.13	.11	.89	8.07	.000
Push-ups	1.04	.11	.84	7.60	.000
Pull-ups	.54	.10	.60	5.97	.000
Long-distance run	.74	.10	.52	5.22	.000

[a]ES = (Program g – Standard Training g) where the standard training g is the appropriate value from Table 4.

[b]z = ES/SE_g.

Table 9

Results of Knapik et al. (2004) Modified Calisthenics Program in Advanced Training

Outcome	Gender	g	SE	ES[a]	z[b]	Sig
Sit-ups	Men	.38	.04	.14	3.45	.000
	Women	.43	.11	.19	1.71	.044
Push-ups	Men	.27	.04	.07	1.65	.049
	Women	.35	.11	.15	1.33	.092
Long-distance run	Men	.15	.04	-.07	-1.70	.045
	Women	.23	.11	.01	.11	.457

[a]ES = (Program g – Standard Training g) where the standard training g is the appropriate value from Table 4.

[b]z = ES/SE_g.

REPORT DOCUMENTATION PAGE

1. REPORT DATE (DD MM YY)
25 10 10

2. REPORT TYPE
Technical Report

3. DATES COVERED (from – to)
April 2009–October 2010

4. TITLE
Effects of Physical Training In Military Populations: A Meta-Analytic Summary

5a. Contract Number:
5b. Grant Number:
5c. Program Element Number:
5d. Project Number:
5e. Task Number:
5f. Work Unit Number: 60704

6. AUTHORS
Vickers, Ross R. Jr., Barnard, Amanda C.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Commanding Officer
Naval Health Research Center
140 Sylvester Rd
San Diego, CA 92106-3521

8. PERFORMING ORGANIZATION REPORT NUMBER
11-17

8. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)

Commanding Officer	Commander
Naval Medical Research Center	Navy Medicine Support Command
503 Robert Grant Ave	P.O. Box 140
Silver Spring, MD 20910-7500	Jacksonville, FL 32212-0140

10. SPONSOR/MONITOR'S ACRONYM(S)
NMRC/NMSC

11. SPONSOR/MONITOR'S REPORT NUMBER(s)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Military physical training should increase combat readiness. Ability-performance modeling studies have shown that muscular strength and cardiovascular endurance are the keys to effective task performance, so training that improves these abilities improves readiness. This meta-analysis, which synthesized military physical training studies, showed that standard training practices produced large gains in muscular endurance and cardiovascular endurance. Standard training practices produced only minor improvements in muscular strength. Situational constraints limit the training options for military units, but some experimental programs have shown that training can be redesigned to promote muscular strength within those constraints. Modifications to past training practices have the potential to better align training practices with readiness requirements.

15. SUBJECT TERMS
military training, basic training, physical capabilities, muscular strength, muscular endurance, cardiovascular endurance

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
UNCL	UNCL	UNCL	UNCL	32

18a. NAME OF RESPONSIBLE PERSON
Commanding Officer

18b. TELEPHONE NUMBER (INCLUDING AREA CODE)
COMM/DSN: (619) 553-8429

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18